

Building Cost-Effective and Affordable Medical Solutions Using the Design Thinking Approach

Abena Engmann¹, Mammie Hutchful Nortey², Collins C Ngwakwe³

Abstract. Nowadays, healthcare innovation is the main tool that improves the provision of medical care in developing countries, especially in countries with low resources. This research case presents the innovation journey of Goliath Robotics, a startup company in sub-Saharan Africa, specifically Ghana that operates in the health space and produces electric wheelchairs. The case focuses on three theories, particularly the resource-based view, effectuation theory and the bottom of the pyramid integrated with the design thinking process to show how these theories can be applied together in a business model to achieve affordability, accessibility and sustainability. The co-founders not only strive to source raw materials themselves but also fill in skills gaps required to produce the wheelchairs, as well as overcome a bevy of technical hurdles in their startup journey. The research aims to bridge the literature gap regarding entrepreneurs producing affordable health solutions using the design thinking approach in underserved markets. It also delves into the importance of involving various stakeholders in developing solutions. The paper applied a case study approach. Data was collected using interviews, which were recorded, transcribed, and data analyzed interpretively. The study results show that integrating these theories creates a comprehensive framework for guiding innovation in healthcare delivery and the end user's involvement at the base of the pyramid to develop appropriate, cost-effective solutions. By integrating these theories, entrepreneurs and firms can use design thinking to identify opportunities to serve low-income populations, leverage local, available and affordable resources and internal capabilities, make effective decisions and adapt to uncertainty. Researchers can test this framework in other markets or developing countries for future studies.

Keywords: entrepreneurship, innovation, health, resource constraint, co-creation, design thinking.

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Створення економічно ефективних і доступних медичних рішень за допомогою дизайн-мислення

Анотація. Сьогодні інновації в галузі охорони здоров'я є основним інструментом, який покращує надання медичної допомоги в країнах, що розвиваються, особливо в країнах з обмеженими ресурсами. У цьому дослідницькому прикладі представлено інноваційну подорож Goliath Robotics, стартап-компанії в Африці на південь від Сахари, зокрема в Гані, яка працює в галузі охорони здоров'я та виробляє електричні інвалідні візки. Дослідження зосереджене на трьох теоріях, зокрема погляді на основі ресурсів, теорії ефекту та нижній частині піраміди, інтегрованих у процес дизайн-мислення, щоб показати, як ці теорії можна застосувати разом у бізнес-моделі для досягнення доступності та стійкості. Співзасновники не лише прагнуть самостійно отримувати сировину, але й заповнюють прогалини в навичках, необхідних для виробництва інвалідних візків, а також долають низку технічних перешкод на своєму стартовому шляху. Дослідження має на меті заповнити прогалину в науковій літературі щодо стратегій розвитку підприємств, використовуючи підхід дизайн-мислення на недостатньо забезпечених ресурсами ринках. У ньому також розглядається важливість залучення різних зацікавлених сторін до розробки рішень. У статті застосовано підхід тематичного дослідження. Дані були зібрані за допомогою інтерв'ю, які були записані, транскрибовані, а дані були проаналізовані шляхом інтерпретації. Результати дослідження показують, що інтеграція цих теорій створює всеохоплюючу основу для спрямування інновацій для надання медичних послуг і залучення кінцевих користувачів до основи піраміди для розробки відповідних, економічно ефективних рішень. Інтегруючи ці теорії, підприємці та фірми можуть використовувати дизайн-мислення для виявлення можливостей обслуговування населення з низьким рівнем доходу, використання місцевих доступних ресурсів і внутрішніх можливостей, прийняття ефективних рішень і адаптації до невизначеності. В майбутніх дослідженнях дослідники можуть перевірити цю структуру на інших ринках або в країнах, що розвиваються.

Ключові слова: підприємництво, інновації, охорона здоров'я, ресурсні обмеження, співтворчість, дизайн-мислення.

INTRODUCTION

Healthcare delivery is awful in most developing countries (Essounga, 2018) partly due to insufficient budgetary allocations, lack of human resources and poor leadership and management (Overhoff et al., 2023), lack of functional medical devices (Overhoff et al., 2023), lack of appropriate medical devices (Compton et al., 2018), lack of reliable source of electricity and clean running water, lack of access to parts and consumables for medical devices (Saidi & Douglas, 2022). Innovations in healthcare will help improve healthcare delivery in developing countries, especially in low-resource settings.

This case study aims to provide some comprehensive insights into designing affordable and affordable health innovations for use in low-resource settings. Up to 40% of imported medical devices in under-resourced areas in low and middle-income countries are unusable (Hu et al., 2022). The non-usability stems from the fact that these devices were not made to function in low-resource settings but in high-income countries that have efficient healthcare systems and resources to run these devices (Overhoff et al., 2023). The study contributes to a theoretical discourse and provides practical insights for entrepreneurs seeking to improve healthcare delivery in low-resource settings.

LITERATURE REVIEW

Organizations have recently sought cost savings, improved efficiency and reduced cycle time (Kabra & Mukerjee, 2024). Applying design thinking in health care can improve innovation, effectiveness and efficiency through increased attention to the needs of the patient and the provider (Altman M, Huang TT, 2018). Design thinking is applied in different healthcare settings and health conditions. Alman et al. (2018) find that in comparison with conventional expert-driven healthcare methods, design thinking may lead to improvements in effective interventions arising from improved usability and acceptability of healthcare products and services. The need for innovative healthcare delivery through design thinking has also been advocated for application to process innovation (Houssaini et al., 2024). The application of design thinking in healthcare is important as the landscape of health has seen radical changes in the past decade and has continued to grapple with a variety of challenges regarding variations in quality and increasing cost of care delivery (Houssaini et al., 2024). Given the ever-increasing health challenges, increasing healthcare sector competitiveness requires organizations to seek alternative options to improve their healthcare offerings and processes. To achieve this,

medical service providers would require disruptive approaches and/or strategies to enhance the treatment process and bolster the creation of transformational care to offer a high level of patient care and patient satisfaction. Accordingly, design thinking in healthcare offers the desired problem-solving solution to approach the complex challenges towards meeting the needs of both healthcare providers and patients (Houssaini et al., 2024).

Existing empirical literature highlights different scenarios where design thinking applications may enhance efficiency and effectiveness in operations, services, production, etcetera (Brown, 2018; Wattanasupachoke, 2012). Since strategies that bolster effectiveness and efficiency lead to the optimization of resources, this implies that design thinking can improve cost efficiency. Accordingly, the concept of design thinking is constantly being applied by strategists in many organizations as it is strongly viewed as a vital process for innovative creativity to enhance effective business development (Wattanasupachoke, 2012). It is thus gaining constant recognition that the design thinking process has the propensity to add significant value to products' ability to remain unique from other competing products, hence creating and/or increasing brand premium and image. Importantly, Wattanasupachoke (2012) found that design thinking enhances the optimization of operating capacity and reduces production costs as manufacturing processes become less complicated and seamless. The manufacturing process simplification implicit in design thinking enhances greater competitive advantage since design thinking bolsters product or service efficiency and differentiation (Wattanasupachoke, 2012).

Brown (2018) concurs with the findings of Wattanasupachoke (2012) and expatiates further that design thinking assists in identifying users' demand preferences with greater accuracy, ultimately leading to the development of effective customer-preferred products and services. According to Brown (2018), the application of design thinking assists in reducing resource wastages and eliminating undesirable product features, which leads to more consumer attraction, product acquisition and customer satisfaction. Design thinking also enhances risk management and reduces trial-and-error costs as design thinking production is customer-centric, and the refining stage is customer-inclusive.

Davis et al. (2014) highlight that healthcare schemes continuously endure prevalent inadequacies, high prices, and hence inequitable access and varying qualities, which are diverse among nations. Hence, Herzlinger et al. (2014) indicate that innovation strategies such as design thinking are among other competencies that may improve productivity and productivity efficiency in healthcare services. Innovation may be very challenging in healthcare services given the complexity and uniqueness of healthcare service provisioning, which thus requires a spontaneous response with efficient strategies. This, therefore, elevates the need for conventional healthcare systems to adopt innovativeness, adaptiveness and cost-effectiveness in healthcare systems (DeSalvo et al., 2016; Herzlinger et al., 2014).

THEORETICAL FRAMEWORK

The case highlights three theories that support the goals of affordability and accessibility in producing wheelchairs. The resource-based view (RBV) is a commonly used lens for evaluating firms' performance against their competitors. In addition to this theory, we believe that adding a diversity of theoretical views to assess firms' performance and sustainability can enrich our understanding of firms' strategies. The additional theories are the Bottom of the Pyramid (BoP) theory, the Effectuation theory and the Design thinking approach. Each of these theories gives a distinctive lens to understand the process of designing and producing for a resource-constrained market. The BoP theory is important as it details what it means to serve in low-resource markets. The RBV shows how firms gain a competitive market advantage and sustain their businesses. The effectuation theory and design thinking help us to see the importance of iteration and co-creation to ensure affordability and accessibility.

Resource-Based View (RBV)

The resource-based view believes that a firm's resources help it recognize sources of sustained competitive advantage because of its heterogeneous, inimitable, rare and valuable resources that are not perfectly mobile across firms in an industry (Barney, 1991). The resource-based view measures a firm's performance against competitors within the same industry by looking at its internal resources and abilities. Peteraf (1993) indicates that external opportunities need to be matched to a firm's internal resources to have a sustained competitive advantage. Barney (1991) classified the resources into physical capital, human capital and organizational capital resources. These resources do not work entirely independently (Peteraf, 1993), cannot have strategically equivalent substitutes and influence the firm's strategic progress. However, not all resources are relevant at the same time every time (Barney, 1991). This case showcases the use of locally sourced low-cost materials to manufacture wheelchairs for those who cannot afford to buy them. Using these unique raw materials creates a sustained competitive advantage over the firms that import these wheelchairs. Because firms would want to create sustained competitive advantage, they would consciously look for unique resources that would help them produce affordable wheelchairs efficiently and at a lower cost, hence making the product more affordable, which does not include raw materials but also partnerships, just as highlighted in this case. In other words, the resource-based view leads to identifying strategic resources such as skilled labour and local materials that help give a sustained competitive advantage to firms, and that is exactly what the case shows the founders did.

Effectuation Theory

Sarasvathy's (2001) effectuation theory postulates the entrepreneurial approach where the entrepreneur uses available resources to explore and select different potential effects that can be generated with these resources. In other words, the available resources are leveraged to create solutions. Entrepreneurs that use the effectuation approach commence their venture with a broad objective, which progresses steadily with the use of new information, adapting to emerging opportunities and modifications made to the initial objective (Chandler et al., 2011). Using available low-cost raw materials reflects an effectual approach to making these wheelchairs. Another approach by the team that reflected effectual thinking was the team's ability to adapt to changing conditions, especially when making the individual parts of the wheelchairs by leveraging partnerships and using customer insights to innovate.

Design Thinking – The Design Thinking Process

“Design thinking is a human-centred approach to innovation that draws from the designer's toolkit to integrate the needs of people, the possibilities of technology, and the requirements for business success.” – Tim Brown, CEO of IDEO. It is an approach to problem-solving that combines the possibilities of technology, the needs of people and the requirements for success. It is an iterative framework with 5 stages: Empathize, Define, Ideate, Prototype and Test (Interaction Design Foundation, 2021).

1. Empathize: In order for the innovator to be able to empathize which is the first stage of process, the designer needs to understand the needs of the people the solution is being created for in relation to a particular problem. Empathizing is a critical stage in the process, setting the tone for innovation.

2. Define: At this stage, all the information obtained through interviews and observation is synthesized to frame the problem clearly.

These first two stages form the first diamond, and it is called problem space mapping. This basically means that the problem at this stage is being properly unpacked to better understand the actual challenge.

The second diamond comprises the next three stages and is referred to as the solution space.

1. Ideation: Here, possible solutions are explored, and design thinking at this stage encourages as many ideas as possible.

2. Prototyping: Prototyping is where the proposed solution obtained during the ideation stage is created at the lowest cost possible with all its features. Various prototyping methods, such as sketching and storyboarding, can be used.

3. Testing: During the testing stage, the prototype is tested with stakeholders to ascertain if the solution solves the problem.

The case shows that end-user needs were prioritized throughout the wheelchairs' design and manufacturing. The team used the design thinking process. Their lived experiences gave them empathy to understand users' mobility needs and the financial constraints they faced. This empathy also helped design the chair's functionality and enhanced the user's experience.

Base of the Pyramid (BoP) Strategy

Designing low-cost wheelchairs aligns with BoP theory as it addresses the needs of low-income consumers who cannot afford traditional, higher-priced wheelchairs. This theory supports the focus on affordability and functionality adapted to the purchasing power of BoP customers which this case presents. The BoP theory, introduced by Prahalad et al. in the early 2000s, explains how businesses innovate and serve low-income markets by producing affordable products (Vishnoi et al., 2022). The definition of people living at the BoP is those living at or below USD 1500 per annum or at the threshold of USD 1 or 2 per day (Yu et al., 2023). Research also points to the fact that and justifies that BoP is a significant market. Quoting Sheth 2021, Khandker (2023) indicates that the bottom-of-the-pyramid markets globally are projected to be at least \$ 5 trillion annually and are anticipated to grow faster than the world GDP (Sheth, 2021). These markets are usually resource-constrained.

The theory of BoP has evolved over the years, with researchers now classifying BoP into BoP 1.0, BoP 2.0 and recently BoP 3.0, which is still evolving. BoP 1.0 identifies “the poor” as consumers in the niche markets that create value for bigger businesses, while BoP 2.0 regards the poor consumers as co-creators within the local community. BoP 3.0 redefines the role of the poor at the BoP to now being producers to serve the local community (Yu et al., 2023). BoP 2.0's research includes the study of innovations and networks, which are important elements in co-creation. Co-creation requires interaction with other stakeholders. Linna (2013) refers to the mindset of entrepreneurs who operate at the BoP. These entrepreneurs desire to find workable and affordable solutions using easily available resources within the same communities. Solutions are found through many iterations. In BoP 3.0, discussions are beginning to centre around business models, allowing the entrepreneur to align actors and activities connected to create value (Dentchev et al., 2022).

By integrating these theories, entrepreneurs and firms can use design thinking to:

- Identify opportunities to serve low-income populations (BOP);
- Leverage local, available and affordable resources and internal capabilities (RBV);
- Make effective decisions and adapt to uncertainty (Effectuation).

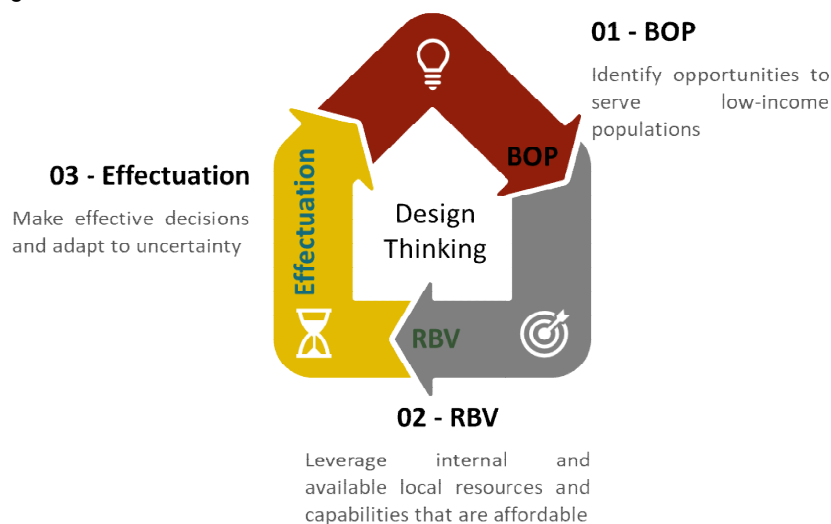


Figure 1. Comprehensive framework for developing health solutions for underserved markets

Source: Developed by the authors.

RESEARCH PURPOSE AND METHODOLOGY

The main motivation is to test a framework of 3 theories combined with Design thinking that can be used to develop health innovations for underserved markets using a real case study. The paper also seeks to provide a better understanding of the iterative process of design thinking and the importance of stakeholder involvement in the design of innovative solutions.

The paper applies a case study design. The data was collected using the interview method, which was recorded and transcribed. Qualitative interpretive text analysis was used to analyze the obtained data.

RESULTS AND DISCUSSION

Derived from the biblical battle between David and Goliath, in which David uses stones/pebbles to defeat Goliath, Goliath Robotics LLC stands tall as a company using innovative and localized means to solve problems heavily impacting society. This story runs deep into the company's philosophy and approach to innovation and problem-solving. As a manufacturing firm with a strong research and development background, Goliath Robotics stands tall amongst its competitors in its niche industry.

"We find issues that seem to be glaring directly at the average Ghanaian and try to solve it cheaply."

Its CEO Barnabas had always wanted to be an entrepreneur – to get his hands on the job making solutions that drove impact. It was no surprise that he decided to expand his school project, which he started with his friend and co-founder, Angela, into what is now Goliath Robotics. Their joint passion for people and making life easier for everyone while paying attention to vital details in product design that leverages their individual strengths in electrical, electronic and software engineering propelled the company to its current heights.

"We knew how each other works, and we're able to really compensate for each other. She does mechanical devices; I do electronics; I build circuit boards. There was really great chemistry between us... I think because

of our added personal experiences with the problem we were going into... there's this level of friendship that ensures we're able to control each other, and we're able to train each other."

From what started as a 2-person venture, Goliath Robotics currently has a staff of 10 individuals. It is entering newer dimensions of production, where they are looking to localize the production of different vital tools and machines. To him and the company, it is more about impact than it is about profits. By actively incorporating the feedback from their potential users and customers into their design thinking processes, the team ensures their designs enhance comfort and usability for their users, which is critical to their success. This has made Goliath Robotics create products that do exactly what they are desired to do (people-driven solutions and innovations), pushing its name to be associated with resilience with an intense touch of youthful audacity.

According to the 2021 Population census by the Ghana Statistical Service, close to 1 million Ghanaians have a form of disability regarding mobility (Ghana Statistical Service, 2023). Inclusive of those temporarily immobile due to health conditions, amongst other factors, the number represents a number of the population that will need aid in the form of wheelchairs; however, given the prices of wheelchairs as compared to the average wage rate, many are left without access to these wheelchairs and even those who are able to cannot afford to have certain upgrades and have to contend with a brand that is not specifically tailored to the prevailing weather conditions and landscape. Historically, many interventions, including donations by churches and non-profit organizations, have been noted to alleviate the situation. However, the issue still exists: they are not tailored to the ecosystem.

"...We will talk about how bumpy it is and how they're unable to really service it."

For them, finding access to wheelchairs and even those that make it easier for them to navigate the

undulating nature of the landscape in Ghana is a better bet and a greater solution to their problem. Goliath Robotics comes in as a saviour for this marginalized population of the country as well as a necessary innovator for the country's health sector, which is subjected to many challenges. For Barnabas and Andrewla, the innovation was one that struck home due to the closeness they had with people who needed the solution, but the wheelchair speaks to a deep problem within the healthcare sector of the country. However, the journey from it being a simple idea to what it is now was not a walk in the park for the young entrepreneurs.

Empathy Sparks Innovation

What started as an idea for a class course project continued to become a final-year project and is now a fully-fledged product by Goliath Robotics. The backstory of this company goes way back to Andrewla's story with her grandmother.

"She lived with her grandmother for most of her life, and her grandmother was a really strong woman but, at one point, had a stroke and became very dependent on those around her. Andrewla was very young then, and she couldn't lift this woman. She couldn't do much."

Beyond this, Barnabas himself had stayed a couple of months in a wheelchair awaiting surgery some years back, so it came together that their personal experiences with the wheelchair propelled them to revisit it and see how they would have preferred it to be. Additionally, beyond their personal experiences, they knew many people out there needed an affordable solution to the current intervention for immobility.

Design Beyond Specs and Blueprints

To understand the need for this idea, Barnabas took it upon himself to speak directly to users of wheelchairs he found during his hospital visits. This would help him better understand what would work for them in the case of their invention.

"Sometimes, it wasn't a strict survey; It was an open conversation because usually, when people realize that you're trying to use the information, they would tell you things that sound smart or right without actually being very truthful. I'll just spark a conversation, and then we can talk about it in passing."

By understanding the current state of affairs when it comes to the users' needs, Barnabas was able to gather which changes needed to be made to ensure their electric wheelchair, beyond being automated, also worked well for the users. Utilizing empathy in this stage demonstrated Goliath Robotics' core goal of designing and innovating solutions to specific everyday problems that make life easier. Not solely driven by profits, Barnabas and his team sought out ways to ensure their design and invention are both relatable and affordable for those within the income bracket that it was created – ensure product variation.

A Collaborative Canvas

"They were very helpful in getting us some data on wheelchair users and also their income brackets, so

depending on the share within which you fall, your wheelchair could have some automatic seat recliner or warming parts for your feet ..."

By engaging with health professionals and medical experts, Goliath Robotics created electric wheelchairs not just as a solution but as a companion and lifeline that will support its users in more ways than one. The team's decisions included every bit of the users' desires and needs, ensuring they crafted a mobile and more independent extension of the potential users while developing their own individual skills and knowledge base as innovators.

Technical Challenges

Just like it exists for many businesses, especially for manufacturing startups within an emerging ecosystem like Ghana, the difficulties and challenges push innovators like Barnabas to find inventive solutions and pathways to navigate them. For one that merges both technology and healthcare, Goliath faced strong winds during its journey to its current state.

Material Sourcing

One daunting task within the Ghanaian manufacturing ecosystem that Goliath Robotics had to grapple with was finding the right materials for their prototype. Barnabas bemoaned the state of the problem as one that required persistence, money, and the right network to overcome.

"If you're trying to make products that are termed medical grade, there are a lot of things that you need to do to get working very properly. And the problem with that is that you don't have access to the kind of machinery in Ghana to achieve things of that quality."

Building these lightweight, user-specific electric wheelchairs with additional automation that tackled issues with sturdiness and strength against bumpy rides meant finding materials that had to be tailored for the design process. Unfortunately, the curveball was the need to create a cheaper solution – meaning limited importation of materials that would increase the cost of production, resulting in a higher cost to the user. Altogether, Barnabas and his team needed to depend on the scarcity of specialized components and navigate it creatively without affecting functionality and quality.

While having to deal with power supply issues and the right place to start their prototype, among other things, their university's Innovation workshop came in handy. It allowed them the room and space to work for free, allowing them the chance to invest in material sourcing and trading services for inexpensive materials for their production.

"There are certain services that we could have ideally, if we had gone outside elsewhere to do it, would be extremely expensive, but then we are able to offer them some service in exchange for extremely reduced costs."

Time and Resources

For Barnabas and his team, the automation of the electric wheelchair needed to be precise and efficient, with minimal room for some mistakes. The control mechanisms for the wheelchair are needed to achieve a

good balance, allowing the users to smoothly use it without lag, especially as they will be using it in undulating territories that have bumpy rides. Without these specifications, both theoretically and practically precise, the users would struggle with the controls, leading to inefficiencies and possible accidents Goliath Robotics could not afford to have.

“When people give an idea, you ask them to put their idea down as a mockup or as a design. It really helps because then you see what vision they had for the idea proposed... But when you come up with your mockup design, we review everything, so features from one design will usually be merged with another design and features from another design will be taken out. We arrive at the actual final model from all those different models and then define product specifications.”

All these come at the cost of time and resources because for the team to move to prototyping only to find out their fundamentals were faulty will be costlier than the time spent in ideation and product specification. Also, integrating safety features, which is the core of the innovation proved tasking especially with the issue of creating local specialized components.

“I mean, sometimes, the only thing we can do is still proceed with the attempt, and so that means we really have to figure out how we are going to do that piece because there are certain features that, for example, our safety critical on our wheelchairs, we have this anti-tipping mechanism and I mean to do it we needed to bend some pipes in a specific way and we had to make these actuators... we started out, we got there, we realized well, this is not something we can do.”

Skill Gap

Together with the challenges of sourcing materials locally and creating localised versions of the components came one of the strongest challenges Goliath Robotics and Barnabas faced in their prototyping stage. With the focus on local manufacturing and production to keep costs down, the team faced a skill gap involving sourcing skilled workers to create some of these components.

“We used to go to Agbogbloshie to find the people who can mould certain parts for us. When we go there, all they make are these aluminium pots... You ask them for other things, and they say they can't because they don't have the moulds for that... We had to figure out ways, and so now we have a way that we make moulds ourselves, and then we give them the moulds to do our work for us.”*

Navigating this challenge meant being actively involved in a role that was to be outsourced, leading to an additional allocation of time and resources in an unexpected area of production. As disappointing as it was, the team at Goliath Robotics just like biblical David were prepared to meet these challenges full on with an unyielding determination to leave an indelible mark.

Crafting Mobility Against the Odds

* A large metal and scrap waste market in Accra, Ghana.

Goliath Robotics encountered myriad challenges on the journey to becoming who they are today. In jumping these hurdles, they demonstrated a strong capability to adapt quickly to change and embrace newer forms of doing things while leveraging their strengths. Successfully transforming and developing a project of this nature from its initial form showed the impact of breakthroughs in multiple contexts.

Collaborative Team Effort

The 10-member team running Goliath Robotics was pivoted by a strong desire to learn, grow, and lead transformative efforts. Collaboration between different team members performing various roles and the synergy that existed between them fostered excellent communication and chemistry that allowed them to leverage one another's strengths. This highly collaborative space will propel them to develop solutions speedily and effectively while ensuring they meet the users' needs. Knowing the team size is fixed ensures they invest in the right human resources and company attitude for each recruit.

“We just need to know the way you would approach a problem if it was a little beyond you and there's no one to help... In terms of building skills, I think it's easy to teach someone a skill, but for example, the attitude to use that skill in a very proper way, that's what we need to be very much aware of, and if we are able to figure that out, then yes, we can onboard you into the team.”

Iterative Design and Prototyping

Creating an innovation like an electric wheelchair in Ghana based on locally acquired materials requires regular and repetitive testing and revision to ensure that everything is perfect for bringing the idea to life. Without repetitive testing and feedback from users and stakeholders, the entire production process would have failed even at the prototyping stage, causing the team to go back to the old drawing board to put things together again. Though longer, the approach ensured that they knew exactly what was to happen and were adequately prepared for worse-case scenarios and their interventions.

Partnerships and Mentorship

“I used to help people find talent, so while I was in school, I really just started identifying... If I come together with these people, we have a higher chance of being successful at an endeavour...”

With this mindset, Barnabas understood the principle of travelling farther with the right people around him. This Ubuntu attitude made him understand that there was the need to not do everything by himself if he needed to be successful; therefore, when Goliath Robotics was faced with hurdles both internally and externally, the spirit of a united front kicked in to propel them to the next level through delegation and seeking guidance from experts.

“I think being self-aware, honest with yourself, and realizing when things are right or wrong are really important in a team. For example, I ask opinions about designs or features because if I say something a certain

way, people might be more likely to agree because it's from one of us, but I also need to be able to get people to express discomfort or disagreements and things like that freely and openly”.

By outsourcing some parts of production to other firms and people and having a strong team of mentors and advisors, including Dr. Fred (President of the Academic City College), Professors and lecturers from the university, as well as experts within the medical supplies and technology fields, Goliath Robotics surrounded itself with guidance that allowed it to escape common mistakes by tech startups within the ecosystem.

“I'm also extremely intentional about making engagements that allow me to learn things happening in the world right now. I actually have a group of friends who meet every three months. When we meet, we will discuss what people are doing currently. I mean, what kind of technologies are they working with? So there's that cross learning... We could be playing some random game like EVE Online or doing some casual activities to just talk for that long. And I always leave those interactions with a lot of new information.”

Balancing Innovation With Cost-Effectiveness

Standing tall in situations that are rigged to one's disadvantage takes unbridled focus and determination. In the case of Goliath Robotics, trying to manufacture components locally and use locally sourced materials, all while maintaining a high level of quality, meant longer hours and possibly increased production costs. Streamlining their production process and spending time increasing knowledge through research on the types of materials that could be used, where they could be found, and which stronger alternatives existed allowed them to effectively and judiciously cut the production time and increase their turnover.

Access to the Academic City engineering workshop was also helpful to the team in balancing innovation and cost-effectiveness. Barnabas and his team could work in an environment that gave them access to all the necessary equipment at low-to-no cost, thereby increasing the production time and quality and focusing on other elements.

“Academic City has a workshop that they spent \$2.5 million on, and I use it. I work from here; I don't pay electricity. I don't have to buy any of the machinery... With the engineering workshop, I literally have every tool at my disposal. I guess it's really about being able to take good responsibility for things and ensure that no one gets injured. From the workshop, we have access to everything from lift machines to furnaces for melting and stuff like that.”

CONCLUSION

The case presented in this study showcases how resource-based view, effectuation theory and design thinking collectively support the aim of creating affordable wheelchairs, using available resources to improve mobility for underserved markets. Goliath Robotics pushes the boundaries of health, technology and innovation in rough terrain and ecosystems using the design thinking process. The RBV and effectuation give strategic insights into the use of resources and the option of flexible decision-making. For instance, as it advances and explores more dimensions to the works and products it can deliver, Goliath Robotics is building its capacity to handle more work and increase its contribution towards sustainability by improving its production methods and incorporating sustainable raw materials.

Combining the Bottom of the Pyramid with Design Thinking helps design solutions for underserved markets. As it strides towards the future and as the world's technology landscape continues to travel at lightspeed, Goliath Robotics sees itself expanding and making more significant contributions to society as it intensifies its research and development strategies to increase its capacity for more and prepare the team's individual development as well. Additionally, the company foresees moving its aluminium component production in-house to ensure increased quality and lower emission production while maintaining lower production costs, further maintaining its balance between innovation, sustainability and cost-effectiveness.

Being a young force with potential and having demonstrated resilience by overcoming multiple challenges in developing its products, Goliath Robotics is a strong emerging top player in developing assistive technology products in Ghana and Africa. With such expansion and future desires come concerns and thoughts around balancing the need for affordable products and the use of advanced technologies, scaling manufacturing capacity while maintaining high product quality, and ensuring these solutions reach underserved communities and marginalised populations. How will Goliath Robotics continue to achieve this?

For future studies, researchers can test how the framework of the theories explored in this study can be used to guide other entrepreneurs in innovating at a reduced cost, customer-centred health solutions for underserved populations using existing local materials, unique local resources and partnerships. Researchers can also explore how a design thinking approach can be used to ensure iterative product development that considers the changing health needs of the market.

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